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New Directions in Microbial Regulations

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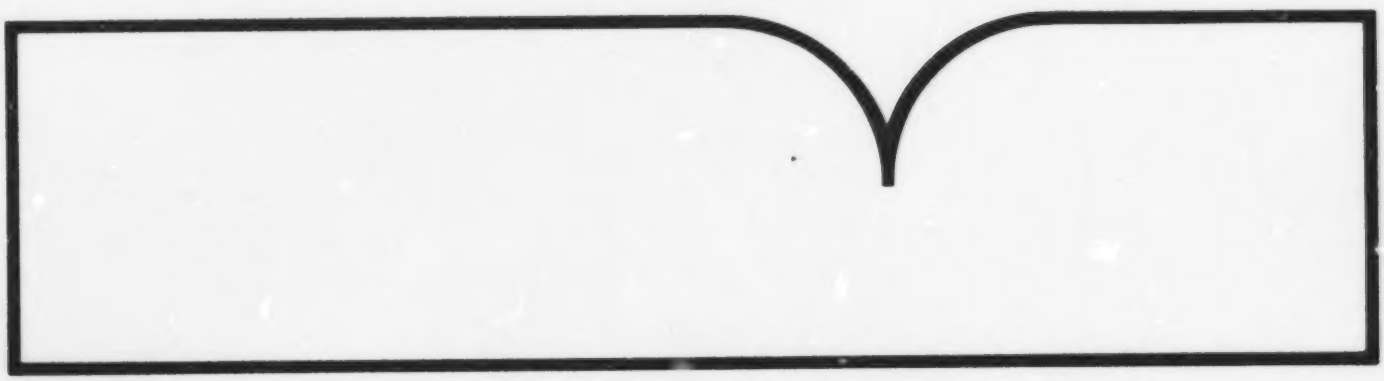

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POTABLE WATER:
NEW DIRECTIONS IN MICROBIAL REGULATIONS

by

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16. ABSTRACT

Waterborne disease outbreaks continue to occur in the United States. Because effective treatment technology is available, the problems appears to be that of upgrading water systems having inadequate barrier protection from contaminated source waters. This paper summarizes consensus views of possible changes to new microbial regulations needed to address weaknesses.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

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Potable Water: New Directions in Microbial Regulations*

Edwin E. Geldreich**

The U.S. Environmental Protection Agency is in the process of developing revised Drinking Water Regulations in response to the requirements of the Safe Drinking Water Act. These revised regulations will involve a comprehensive reassessment of the existing Interim Drinking Water Regulations (1) established in 1976, plus a review of new research information on health risk and engineering process controls to assure a safe public water supply nationwide. The changes brought by these regulation revisions will also have an impact on monitoring procedures and laboratory involvement.

Status of Water Quality

Why the sudden concern for the safety of public water supplies? Based on traditional measures of water quality, public water supplies are meeting current regulation requirements; yet there is significant evidence of increased waterborne outbreaks involving a wide range of pathogenic bacteria, virus and protozoans plus an increasing number of organic and inorganic toxic contaminants (Table 1). Part of this increase in waterborne disease occurrences can be attributed to better reporting of outbreaks but more to the point are the improvements achieved in analytical science that are providing identification of unknown agents and greater sensitivity to trace concentrations of chemicals (2, 3, 4).

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Table 1.

Waterborne Outbreaks in the United States During 1961-1983*

Etiologic Agents	Outbreaks	Cases	Deaths
Bacterial			
Shigella	52	7,462	6
Salmonella	37	19,286	3
Campylobacter	5	4,773	0
Toxigenic E. coli	5	1,188	4
Vibrio	1	17	0
Yersinia	1	16	0
Viral			
Hepatitis A	51	1,626	1
Norwalk	16	3,973	0
Rotavirus	1	1,761	0
Protozoan			
Giardia	84	22,897	0
Entamoeba	3	39	2
Chemical			
Inorganic (metals, nitrate)	29	891	0
Organic (pesticides, herbicides)	21	2,725	7
Unidentified agents	266	86,740	0
TOTAL	572	153,394	2

*Data adapted from Craun (1985); Lippy and Waltrip (1984).

The other aspect to review involves deficiencies in water system design, operation, and maintenance since these problems contribute to waterborne outbreaks. Available information (Table 2) shows that the three major areas of deficiencies cover contaminated untreated groundwater, inadequate or interrupted treatment, and distribution network problems. These reported deficiencies from 1920 to 1983 involved 1,531 water systems and resulted in 415,329 illnesses

Table 2.

Water System Deficiencies Causing Disease Outbreaks, 1920-1983*

Public Water System Deficiencies	Number of Systems	Percent of Deficiencies	Illness Cases
Contaminated, untreated groundwater	661	43.2%	82,528
Inadequate or interrupted treatment	333	21.8%	224,973
Distribution network problems	233	15.2%	83,577
Contaminated, untreated surface water	158	10.3%	12,709
Miscellaneous causes or insufficient evidence	146	9.5%	11,542
TOTALS	1,531	100.0%	415,329

*Data adapted from Craun (1985)

among the customers served. Obviously, the problem needs attention in several areas: redefining minimal treatment requirements, redesigning treatment process control, improving water distribution system protection and operator training. While the proposed revisions of the Drinking Water Regulations will include organic, inorganic, radionuclide and microbial contaminants, this discussion will focus only on microbiological issues and represents a summary of consensus views from the workshops and is not intended to reflect EPA policy.

Regulation Revision Concepts

The Office of Drinking Water held a series of workshops in the past three years with representatives from local water plants, State authorities, consulting engineers, university researchers and Federal experts to discuss specific contaminants that need to be identified, maximum contaminant levels (MCL's) which will be enforceable standards, recommended maximum contaminant levels (RMCL's) which are non-enforceable health goals (Table 3), criteria

Table 3.

Regulation Terminology

Recommended Maximum Contaminant Level (RMCL)

- Non-enforceable health goals
  Example: Turbidity <0.1 NTU

Maximum Contaminant Level (MCL)

- Enforceable standard or concentration limit
- Set as close to RMCL's as feasible
  Example: Turbidity 1.0 NTU

Treatment Option

- Specified only if MCL is not economically or technologically feasible to ascertain level of contaminant.
  Example: pathogen monitoring limitations

for variances to specified minimal treatment and exemptions for a specified time when systems violate MCL's or treatment requirements because of compelling factors including costs (Table 4).

Microbial contamination identified in regulation revisions will continue to include total coliform bacteria and turbidity as routine measurements. In addition, there will be a new concern for limiting heterotrophic plate count and providing protection from virus and Giardia occurrences.

Total Coliform

While some form of coliform standard has existed since 1912, changes in definition, methodology and data interpretation have appeared over the years. In general, the test has provided a practical measure of treatment effectiveness but at times a questionable indication of pathogen occurrence. Part of this weakness may be due to poor detection of stressed coliforms and interference in cultivation by other members of the heterotrophic

Table 4.

Regulation Options

Variance to disinfection requirement

- Data to demonstrate raw water quality provides a water quality equivalent in terms of minimal health risk from virus occurrence as achieved with disinfection.

Variance to filtration requirement

- Data to demonstrate an alternative treatment has equivalent efficiency in removing Giardia.

Exemptions

- Provide specified time to make a correction to MCL violation or treatment requirement for compelling factors including cost.

bacterial population. To address this issue, alternative total coliform media have been developed to improve sensitivity to stressed coliforms. These new membrane filter media are being field tested for acceptance by EPA as alternatives to M-Endo agar and for possible inclusion in the next edition of Standard Methods.

What is new in coliform regulation development is the presence-absence concept, particularly for use by small water systems. These are the systems that monitor their water quality on an infrequent basis each month or every three months and sometimes experience coliform occurrences that are not verified by analysis of another sample until the following month. This situation is intolerable for any effort to evaluate long term water quality conditions based on a quantitative approach. Obviously, what is needed is a better data base on the water quality in order to identify

the problem as one of treatment or distribution. A recommendation in the new regulations will be made to increase frequency of sampling to 5 samples per month for small water systems, but states will be given the discretion to decide which systems need increased monitoring. In any event, the number of data points may still be inadequate to develop any meaningful quantitative information. For this reason, serious consideration will be given to the application of a presence/absence coliform concept (Table 5). This concept places equal concern on all positive samples regardless of density, with a limit designated by a specified percent of positive coliform occurrences permitted. As a hypothetical example, the presence/absence record of compliance could be based on degree of treatment: 5% positive occurrences if the system uses complete treatment, 3% positive limit if only slow sand filtration and disinfection are applied and 1% positive results permitted for untreated groundwater supplies. Because the data base each month will be small, determination of compliance each 30 day period, will require calculations of percent occurrences to be based on sample results recorded over a progression of 12 months.

Exceeding the coliform standard in drinking water may ultimately lead to a boil water order. The concern is a possibility of fecal contamination of the water supply and the associated unacceptable risk to public health. Recent investigations in the field have cast some doubt on the automatic assumption that every coliform occurrence is an indication of increased health risk. Many of the water systems that reported coliform occurrences in their distribution networks found that a Klebsiella species was the predominant coliform. In several other systems, the reported coliform was either Enterobacter or Citrobacter species. In none of these cases was E. coli

Table 5.

Presence/Absence Coliform Concept

- Minimal test sample size 100 mL.
- Equal concern on all positive samples regardless of density.
- Limit designated by specific percent of coliform occurrences permitted.
- Monthly compliance determined from sample results over a progression of 12 months.
- Record of compliance could be based on degree of treatment.

  Examples: Completed treatment: 5% positive limit

  Filtration and disinfection: 3% positive limit

  Untreated groundwater: 1% positive limit

detected, nor were any of these coliforms positive by the fecal coliform test. Furthermore, a check of local hospitals disclosed that there was no waterborne outbreak in progress. The conclusion was that these coliforms were not associated with fecal contamination, but reflected colonization within the distribution pipe environment. Based on this information, public notification may be revised to incorporate specific corrective actions (pipe network flushing, increased free chlorine residuals at ends of the pipe system) when fecal coliforms are not detected. The concern is that repeated issuance of boil water orders when fecal contamination is not evident will result in a lack of public confidence in the municipal water supply, and cause many people to search for alternatives that include private wells, bottled water or point-of-use treatment devices which are not monitored for acceptability.

Turbidity

Water turbidity does have health related implications associated with fibrous mineral particulates (asbestos), humic materials that are trihalomethane precursors and microbial aggregates although harmful amounts may not be measurable by a turbidimeter. Many particulates support microbial habitation, interfere with disinfection, create problems in sample analysis and promote bacterial growth in the distribution system. Furthermore, sudden elevations in water turbidity may also be an indication of increased risk for Giardia cyst passage in surface waters which receive disinfection as the only treatment barrier. Even though turbidity is not a precise measure of particulates of concern, there is merit in achieving turbidities below 1 NTU for finished water. Research evidence suggests that when water turbidity is consistently at 0.2 NTU or lower, there are few microbial concerns. In recognition of this evidence, the RMCL for turbidity may be proposed at 0.1 NTU to prevent passage of aggregated microorganisms, and to minimize the chance passage of Giardia in filtered water. Consideration is being given to keeping the same 1 NTU requirement for finished water released by public water systems. However, monitoring frequency may be specified to be once per day as a minimum, with collections taken at random times during each 24 hour period. The turbidity measurements should preferably be done immediately or within 6 hours of collection because of the unstable nature of many particulates. Since ground water quality is generally constant and the turbidity is usually below 1 NTU, a requirement for measurement of this characteristic in groundwater supplies on a daily basis may not be specified. Guidance on turbidity restrictions for water in the distribution networks may also include a suggested value of 2 NTU. This objective could prove useful in achieving improved water quality characteristics in distribution.

Heterotrophic Plate Count

Limiting the heterotrophic bacterial population can provide a variety of benefits. For instance, profiling this group of bacteria quickly reveals a varying number of organisms that can be opportunistic pathogens, so efforts made to reduce the microbial flora will automatically reduce any potential dangers to high risk individuals in the consumer population. Another benefit would be less interference to coliform detection by either the membrane filter technique or the multiple tube procedure, which at times can be a serious problem in the sample analysis from some small water supplies.

In revising the Federal Regulations, a HPC limit of 500 CFU per mL may be integrated into the total coliform standard. Any coliform test report of confluency or more than 200 colonies on the MF culture or heavy growth with no gas detected in the multiple tube would automatically require an immediate resampling. The retest sample would be analyzed for total coliform and HPC. If this test result again is negative for total coliforms and there are over 500 HPC/mL, there would be a requirement to reduce this bacterial population in the water supply through distribution line flushing and increased disinfectant residual application.

Pathogen Concerns

Focusing regulation on pathogen contamination in drinking water must take into consideration the status of infective dose, availability and cost of methodology and the effectiveness of treatment. As for the minimal infectious dose, one to ten Giardia cysts, fewer than 20 plaque forming virus particles or 10 to 100 viable cells of three Shigella species can produce infection (5). These low dose levels underline the need to establish a zero recommended maximum contaminant level in water supply. Methodology

severely impacts on any attempt to become more specific in terms of a mandatory limit. It is possible to detect Giardia cysts by use of large volume concentration techniques but testing the viability of cysts recovered from environmental samples is very difficult or sometimes not possible. Enterovirus can be detected using Standard Methods techniques but methods are not currently available for routine testing of Norwalk virus, rotavirus and hepatitis A. Current costs of viral analyses have been calculated to range from $100 to $500 per sample which is certainly a limiting economic factor in any extensive monitoring program. Added to that problem is the dilemma of the negative test result. When does a negative pathogen test result provide adequate assurance that the water is free of all pathogenic agents?

Minimal Treatment for Ground Water

Lacking a firm monitoring approach to justify establishment of a zero Giardia or virus level in 100 to 1,000 liters of water sample, the only other option is to specify a treatment requirement that will be a proven, effective barrier to these pathogens. Waterborne outbreaks are a result of either poor source water protection or inadequate treatment. Use of contaminated, untreated ground water was the source of 35.3 percent of waterborne disease outbreaks over a thirty year period (3). Many intermittent contamination problems are caused by the overflow or seepage of sewage, surface water runoff, and periodic flooding over the well field. Studies of these outbreaks implicated hepatitis A, Shigella, Yersinia and Giardia as the most frequent pathogen contaminants. Much can be done in the well field to insulate the water source from intermittent contamination but the corrective measures for pollution abatement over the aquifer are often more

difficult to resolve. Treatment in the form of adequate disinfection can be the most cost effective, public health insurance available provided there is capability for 4 log or more reduction of all pathogens.

It is important to note that there are significant differences in organism inactivation rates by a given disinfectant concentration. Disinfection effectiveness is controlled by the concentration of disinfectant (C) and time of contact (T) and is further modified by other variables including temperature, pH, organisms, disinfectant demand, cell aggregates and disinfectant mixing rates. Order of organism resistance to inactivation by disinfection is generally considered to be:

Coliform < virus < protozoan cysts

The general order of disinfection efficiency, based on coliform inactivation is:

Ozone > Chlorine dioxide > Hypochlorous acid > Hypochlorite ion > Chloramines

Decreasing Efficiency →

Recognizing these caveats, EPA is proposing that all groundwater supplies receive mandatory disinfection. In small water systems, the disinfectant residual of plant effluent would be monitored once per day as a minimum. Free chlorine would not be recommended in systems that have a trihalomethane problem.

Nationwide, there are a number of groundwater systems that are of excellent quality, meeting all of the current standards for drinking water. On a case by case basis, a variance to the treatment requirement would be granted provided there is evidence that the nature of the untreated water

is of such high quality that treatment is not necessary to protect consumer's health. The evidence required would involve extensive monitoring over a 12 month period, no previous history of an outbreak and a sanitary survey done periodically to establish the integrity of the supply. Thus any variance from mandatory disinfection of groundwater would dictate a conservative set of safety factors.

Minimal Treatment for Surface Waters

Surface waters, unlike protected aquifers, are subject to wide fluctuations in quality caused by up-stream pollutional discharges and stormwater runoff over the watershed. Impoundment of these raw waters provides some buffering against water quality fluctuations. Storage time and the quiessent nature of water in storage genrally permits a variety of natural self purification factors to reduce the concentration of many organisms of public health concern. To achieve an approximate 50% reduction of bacteria requires one to two days of storage, while one to two months storage time is necessary to reach a 99 percent reduction in the absence of any further contamination. Because of the uncertainty of the reduction levels related to a specific storage time, raw water storage is not generally considered to be a reliable substitution for filtration in many situations. This concern has been intensified in recent years as a result of 84 separate Giardiasis outbreaks reported in water supplies, many of which were the result of treatment deficiencies, including poorly filtered waters. Giardia cysts are more resistant to inactivation by the usual disinfectant concentrations and contact times applied to control bacteria and virus in water supply. The problem is further aggrevated by raw water temperatures ranging from 1 - 5°C under which conditions, conventional disinfection CT values are not

effective. Filtration will provide remarkably high rates of Giardia cyst removal ranging from 95 to 99.9 percent removal with rapid or direct filtration. Use of slow sand filtration or diatomaceous earth filters would increase cyst removal to greater than 99 percent. Thus the revised Federal Regulations may specify a dual treatment barrier for all water supplies using surface waters; filtration to remove Giardia cysts and disinfection to inactivate pathogenic bacteria and viruses.

Is filtration the only option for controlling Giardia in water treatment? Nearly 56 million people drink water from 7,169 public water supplies that use unfiltered surface waters. This total involves numerous small supplies as well as the big metropolitan areas of New York, Seattle, San Francisco, and Boston. Why have these supplies escaped the risk of giardiasis? There may be a variety of interrelated factors. Two of the treatment conditions that appear important are long disinfectant contact time measured in several hours or more (not minutes) coupled to the use of chloramine disinfection. Achieving acceptance for a variance to the filtration requirement could involve an increased monitoring effort on the raw source water and plant effluents to continually demonstrate that the source water is of low risk and that minimal treatment (disinfection) is producing the same quality of water expected of a dual barrier (filtration and disinfection). An active watershed management program is essential and would include monitoring the resident wild life population for Giardia, identifying sources of sewage discharges, and determining the sewage effluent quality and impact on drainage basin streams. Documenting the absence of any waterborne disease outbreak using past and present public health records in the community would be another critical factor for variance acceptance. Of course, the source water and

plant effluent would be monitored for any occurrence of Giardia cysts, regardless of viability test limitations. Heterotrophic plate count densities below 10 organisms per mL of plant effluent and disinfectant CT information supported by continuous monitoring of disinfectant residual of plant effluent would complete the data base requirements.

Impact on Laboratory Involvement

Revised Federal Regulations will demand more laboratory information in order to resolve non-compliance issues related to coliform occurrences in water supplies. For example, the number of samples submitted from small water systems for coliform analysis can be expected to increase if the presence/absence coliform concept is chosen for compliance purposes. This concept could be introduced by changing the reporting of results from either the traditional multiple tube procedure or the membrane filter test to a coliform presence or absence in each test sample. As another testing alternative, use of the procedure involving presence/absence broth and a single 100 mL test portion for samples could be selected.

Identification of coliforms isolated from water samples collected in the distribution network will become an important step in the determination of coliform significance in public water supplies. Supplemental to this data could be a requirement to verify whether or not the source of these organisms is fecal contamination and therefore dictate a boil water order, or of environmental nature associated with pipe colonization and biofilm development.

Increased laboratory involvement will also result from the need to justify case by case variances to restructuring minimal treatment requirements for groundwater and surface water sources. In addition to intensifying coliform monitoring of these special systems, there will be more frequent

measurements of the heterotrophic bacterial population to gather base-line data on treatment modification effects, early signals of bacterial growth in the distribution network and evidence of interference problems with coliform detection. Of particular concern with the HPC measurement will be the selection of an optimum medium and incubation time-temperature combination for each purpose. HPC data on treatment process effluents may be optimized when derived from R-2A medium and 28°C incubation for 7 days. The trade-off for a better measure of the surviving heterotrophic population is the time frame. While these data may be only a historical recording of past treatment performance, the information is still vital to evaluating engineering control measures. Research evidence has shown that HPC densities above 1,000 colony forming units per mL often interferes with coliform detection by either the multiple tube or membrane filter procedures. Monitoring the distribution system for early signals of bacterial regrowth can be done on any of the three HPC media (R-2A, M-HPC or SPC agars) with incubation time set at 28°C for 7 days. What organisms are involved in early regrowth in the pipe environment is not completely understood but their activity is reflected in the increased heterotrophic bacterial densities detected on these media.

Summary

Waterborne disease outbreaks continue to occur in this country contrary to a popular assumption that all of our problems in water supply are caused by chemical pollutants. There is no excuse for exposure to these microbial risks since effective treatment technology is available. The problem appears to be one of up-grading those water systems with inadequate barrier protection from contaminated source waters. New microbial regulations are needed to address these weaknesses and are now being promulgated by the Office of

Drinking Water, based on new research information and field experiences. It is important to note that while this paper presented a summary of consensus views on possible changes, it does not necessarily reflect the final EPA policy, In any event, expanded monitoring to ensure that treatment has made the water safe is on the horizon and we in the laboratory should be ready to accept the challenge to provide the data to prove it.

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